Memorandum

To: File

CC:

From: Chris Garrett, SWCA

Date: October 30, 2013

Re: Review of Available Depth of Flow Information on Cienega Creek and Empire Gulch and Protocol for Estimating Impacts to Streamflow

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Public comments were received on the Preliminary Administrative FEIS that was distributed to the cooperating agencies on July 1, 2013, concerning the analysis of impacts to riparian areas and streamflow in Cienega Creek and Empire Gulch. In particular, USEPA suggested that a "risk assessment" approach be used to address riparian impacts, assessing the range of drawdown that could occur and the impacts that could result under each drawdown scenario, rather than relying on a single outcome. A revised approach along these lines was provided for review by the USEPA in late September 2013, and based on further comments additional revisions have been made. The purpose of this memo is to document the available data, assumptions, and approach used for predicting impacts to streamflow in Cienega Creek and Empire Gulch.

Typical Depth of Flow

One key aspect of assessing potential impacts to streamflow from groundwater drawdown is to identify typical depth of flow that occurs in the channel. Three sources of data were identified for Cienega Creek and Empire Gulch:

- Stage and flow measurements on the USGS Gage on Cienega Creek near Sonoita (gage no. 09484550). For detailed stage measurements, the period of record for this gage is from October 1, 2007 through present (October 28, 2013), and approximately 205,300 individual stage measurements are available for review. Daily flow measurements are also available since 2001, and although stage detailed stage measurements are not available, these flow values can be converted using a rating curve. The USGS gage is located approximately 17.4 miles above the confluence with Davidson Canyon.

- Depth and flow measurements collected as part of water quality sampling on Cienega Creek (these data were obtained from ADEQ). Five locations in particular are located along Upper Cienega Creek: Cienega Creek below Pump Canyon, Cienega Creek below Sandford Canyon, Cienega Creek at Stevenson Canyon, Cienega Creek at Cedar Canyon, and Cienega Creek below Stevenson Canyon. Together, these sampling locations range from 16.2 to 21.3 miles above the confluence of Davidson Canyon, and represent the region of Upper Cienega Creek that is of the most concern from groundwater drawdown. The period of record for these measurements is from November 1991 through April 2006. These data consist of spot measurements only; between the five locations a total of 27 spot measurements are available.

- Very little information is available for Empire Gulch, but one report was reviewed with some pertinent information (Bodner and Simms 2008). In particular, Figure 26 from this report contains data from two spot measurements on Empire Gulch. Additional data were requested from any possible parties (Pima County, EPA, and BLM) but as of yet no additional data have been identified.

<u>Review of USGS Gage Data</u>

The data for USGS gage no. 09484550 represent the most complete and continuous source of information concerning depth of flow on Cienega Creek. During the period of record, flow ranged from 0 cubic feet per second (cfs) to 2,060 cfs. The period of zero flow occurred during May/June 2010. Based on field reconnaissance conducted by the Coronado hydrology specialist, the gage consists of a v-notch weir (see figure 1).


Figure 1. Existing Streamgage 09484550

In order to be used for predicting impacts from drawdown, stage measurements or flow measurements need to be converted into depth of water. The USGS was contacted in order to obtain their rating curve for this gage, which was provided to the Forest. This allows the daily average streamflow measurements to be converted to either a stage measurement or a depth of water. The full period of record (2001-2013) is shown below (figure 2).

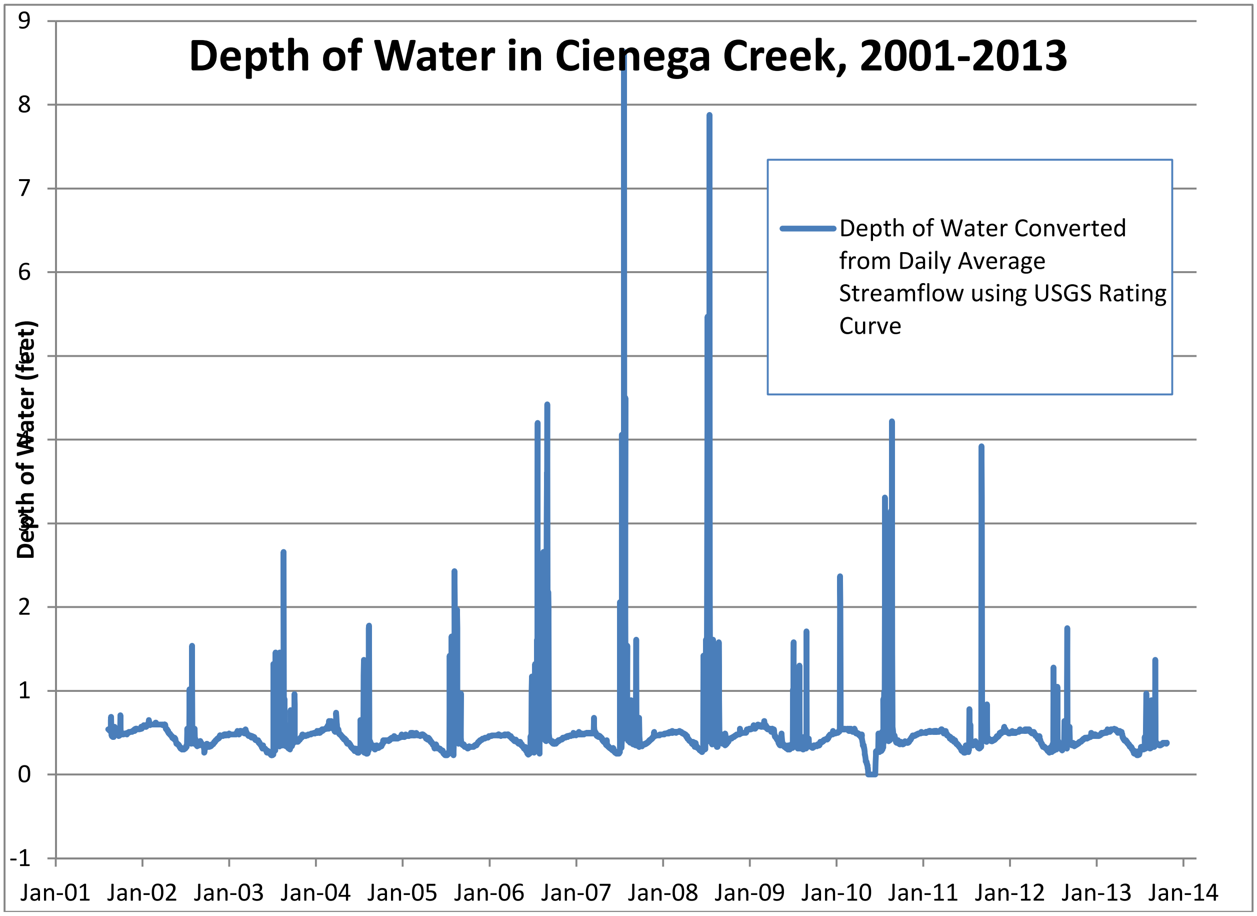

Figure 2. Depth of water data for streamgage, for entire period of record

Review of Point Measurements

The 27 point measurements for depth of water associated with water quality sampling at the other five locations on Cienega Creek range from 0.16 feet to 1.25 feet. These locations are shown in relation to the streamgage are shown below.

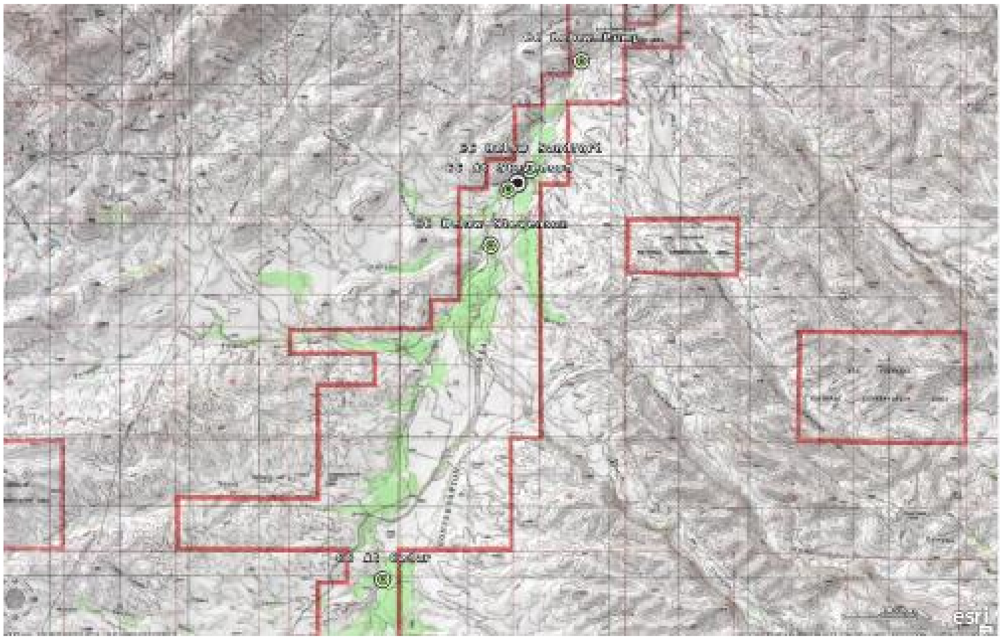

Figure 3. Locations of other water level measurement locations on Cienega Creek in relation to streamgage

<u>Review of Empire Gulch Measurements</u>

These measurements are of limited use, since they only describe two snapshots in time at an unspecified time during the year (1993 and 2006). In 1993, the total wetted depth of the channel cross-section appears to be about 0.2 feet. In 2006, the total wetted depth of the channel cross-section appears to be about 1.5 feet.

Selection of Typical Flow Regime

The most detailed source of data for use in the analysis of potential impacts to Cienega Creek/Empire Gulch from drawdown is the USGS stage data. However, this source of data is not useful for the analysis unless it can be shown to be reasonably representative of Upper Cienega Creek and Empire Gulch as a whole.

The 29 available point measurements (27 for Upper Cienega Creek and 2 for Empire Gulch) are shown in the following table and compared to the median monthly water depth from the USGS streamgage (table 1). In addition, since the streamgage data and some of the point measurements overlap in time, the depth of water on a specific day can be compared (table 2).

Table 1. Comparison of USGS Streamgage water levels to water levels elsewhere on Cienega Creek and Empire Gulch												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
USGS Streamgage 09484550 Median Depth of Water	0.46	0.48	0.49	0.44	0.32	0.24	0.28	0.31	0.33	0.33	0.38	0.45
Cienega Creek at Cedar Canyon		0.27	0.3	0.29					0.22			0.21 0.16
Cienega Creek at Stevenson Canyon	0.66	0.65	0.29	0.75	0.67 0.23			0.59 0.18	0.24		0.36 1.12 0.46	0.29
Cienega Creek below Pump Canyon		0.27	0.32	1.25					0.53			0.55 0.66
Cienega Creek below Sandford Canyon									0.36			
Cienega Creek below Stevenson Canyon									0.24			
Range at all Cienega Creek locations (but gage)	**0.66**	**0.27-0.65**	**0.290.32**	**0.29-1.25**	**0.23-0.67**	**-**	**-**	**0.18-0.59**	**0.22-0.53**	**-**	**0.36-1.12**	**0.16-0.66**
Empire Gulch	0.2 (no date) 1.5 (no date)											

Table 2. Comparison of Depth of Water on Specific Dates		
Location and Date	**Point Measurement Depth of Water**	**Depth of Water at Streamgage**
Cienega Creek at Cedar Canyon - 9/18/01	0.22	0.54
Cienega Creek at Cedar Canyon – 12/17/01	0.16	0.54
Cienega Creek at Cedar Canyon – 3/20/02	0.3	0.6
Cienega Creek at Stevenson Canyon – 9/27/05	0.24	0.33
Cienega Creek at Stevenson Canyon – 12/7/05	0.29	0.42
Cienega Creek at Stevenson Canyon – 2/16/06	0.65	0.48
Cienega Creek at Stevenson Canyon – 4/12/06	0.75	0.43
Cienega Creek Below Pump Canyon – 9/18/01	0.53	0.54
Cienega Creek Below Pump Canyon – 12/17/01	0.66	0.54
Cienega Creek Below Pump Canyon – 3/20/02	0.32	0.6

Applicability of Streamgage as a Surrogate to Upper Cienega Creek

Water levels clearly vary widely in Cienega Creek. This is not unexpected, as channel geometry and flow characteristics are highly variable, even within short distances. The streamgage depth of water values fall more-or-less in the middle of the observed data: 12 observed depth measurements are higher than the streamgage, 15 observed depth measurements are lower than the streamgage (figure 4). The comparison of specific dates is more biased: 3 observed depth measurements are higher than the streamgage, 7 observed depth measurements are lower than the streamgage.

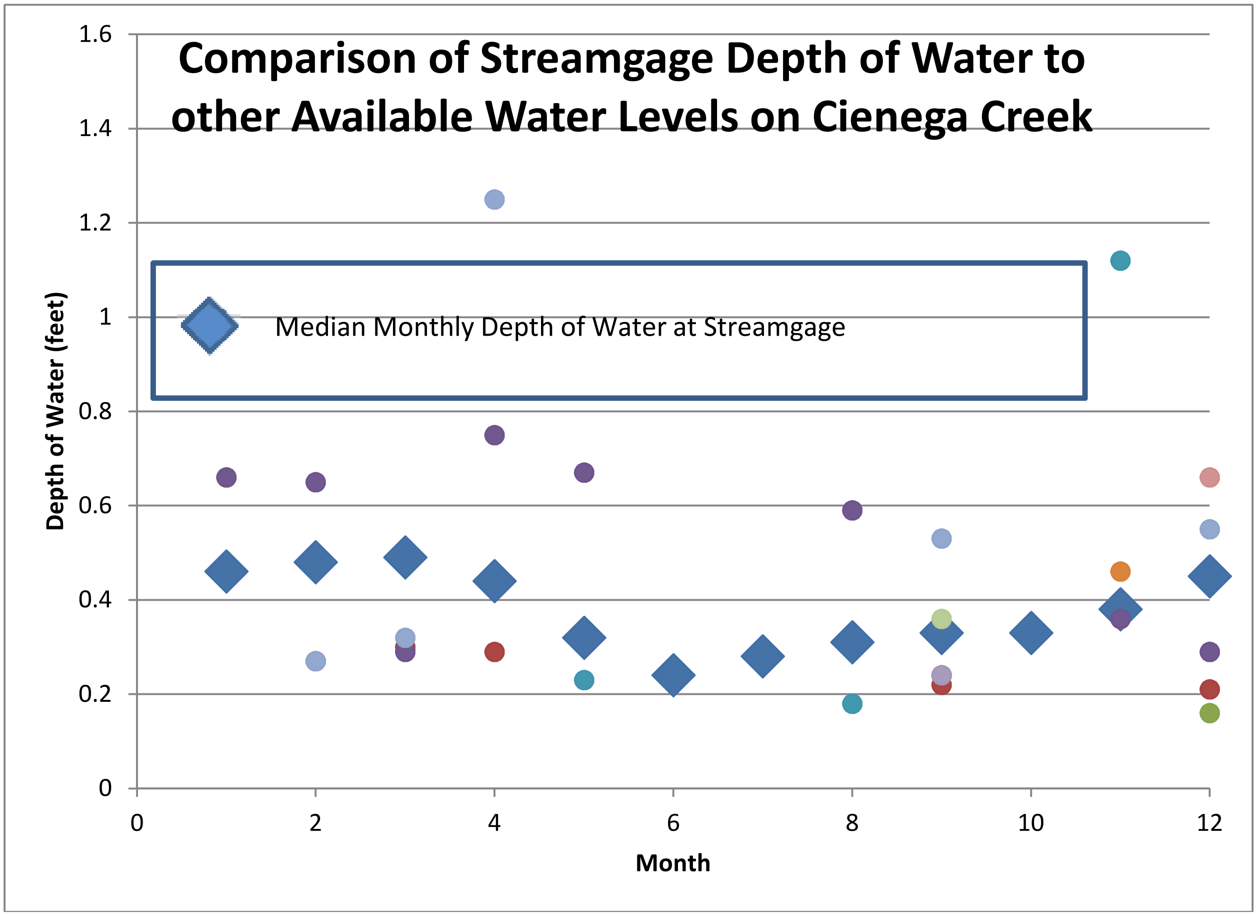

Figure 4. Comparison of streamgage median water levels to other water level measurements on Cienega Creek

The use of the streamgage as a surrogate for all of Upper Cienega Creek seems reasonable as an approximation of typical conditions along Upper Cienega Creek, given the limitations of the analysis. Actual impacts to streamflow at any given location along Upper Cienega Creek would depend on the specific channel geometry, hydraulic connection with the regional aquifer, and riparian vegetation characteristics at a specific location. This is evident from the high longitudinal variability exhibited during annual stream presence/absence monitoring conducted downstream within the Pima County Cienega Creek Natural Preserve, in which some sections of the creek are entirely dry while other areas of the creek remain wet. In addition, at any given location the channel geometry is constantly shifting over time in response to sediment loads and changes in flow unless there is good channel control, such as at the USGS streamgage. It is impossible to predict exactly how any given cross-section would change over the extremely long periods of time used in the analysis.

The analysis is not intended to capture these nuances. The purpose of the analysis is to generalize the potential impacts that would occur along a long stretch of channel, recognizing that localized impacts can be greater or less, just as impacts during drought cycles can be greater and impacts during wet climatic cycles can be less. The streamgage data appear to be reasonable for this type of generalized analysis, to use as a surrogate for likely impacts along all of Upper Cienega Creek.

Applicability of Streamgage as a Surrogate to Empire Gulch and Gardner Canyon

The applicability of the Cienega Creek streamgage as a surrogate for flow impacts along Empire Gulch is not as well justified, given the paucity of measured water depths in Empire Gulch. The Cienega Creek streamgage falls within the range observed in Empire Gulch, but the entire set of data points numbers only two.

The prediction of impacts looks at several points in time: near-term (up to 50 years after closure), and long-term (up to 1,000-years after closure). At 1,000 years in the future, the relevance of the Cienega Creek gage to Empire Gulch is a moot point, as the drawdowns predicted by the models are great enough to predict significant drying under almost any analysis technique.

In the near-term, based on anecdotal descriptions of Empire Gulch, the Cienega Creek streamgage is probably a reasonable surrogate for lower Empire Gulch near the confluence, but may substantially overestimate water depth farther upstream.

Lacking better water depth information for Empire Gulch, the Cienega Creek streamgage has been used as a surrogate, but the likelihood of flows being shallower farther upstream is explicitly acknowledged in the analysis.

No depth of water or streamflow information has been uncovered for Gardner Canyon. The Cienega Creek streamgage has been used as a surrogate for Gardner Canyon as well, but again the likelihood of flows being shallower is explicitly acknowledged in the analysis.

Prediction of Impacts

During the various rounds of review, the following general concerns were raised:

- The approach was too qualitative.
- The approach was not conservative enough. Critical periods should be given more focus, not just medians or averages.

- The approach used assumptions that were arbitrary and not supported. While recognizing that these assumptions may necessarily be based on professional judgment, they were felt to be too subjective to adequately reflect the potential impacts.
- The approach should rely on a range of impacts, or a risk assessment approach, rather than selecting a single outcome.

The following approach was developed to respond to these concerns. It builds off the strength of having a period of record of detailed water levels along Cienega Creek (2001-present). This period of record is pertinent for several reasons. First, this represents a period of significant drought, and therefore ought to be relatively conservative. Second, this period of record incorporates all of the normal seasonal highs and lows, including the most critically low-flow periods (May/June). Third, this period of record includes periods when Cienega Creek actually dried. This allows us to estimate the probability under existing baseline conditions for Cienega Creek to dry, and estimate the average days per year that dry conditions occur. The probabilities under existing baseline conditions are summarized in table 2. A histogram of existing baseline water levels is shown in figure 5.

Table 2. Percent of time water levels are exceeded during period of record

Depth of Water (feet)	Percent of Time Exceeded
0.6	4.5%
0.55	8.8%
0.5	22.5%
0.45	45.7%
0.4	59.9%
0.35	75.8%
0.3	91.2%
0.25	97.3%
0.2	99.0%
0.15	99.1%
0.1	99.2%
DRY	99.3% (i.e., dry 0.7% of time)

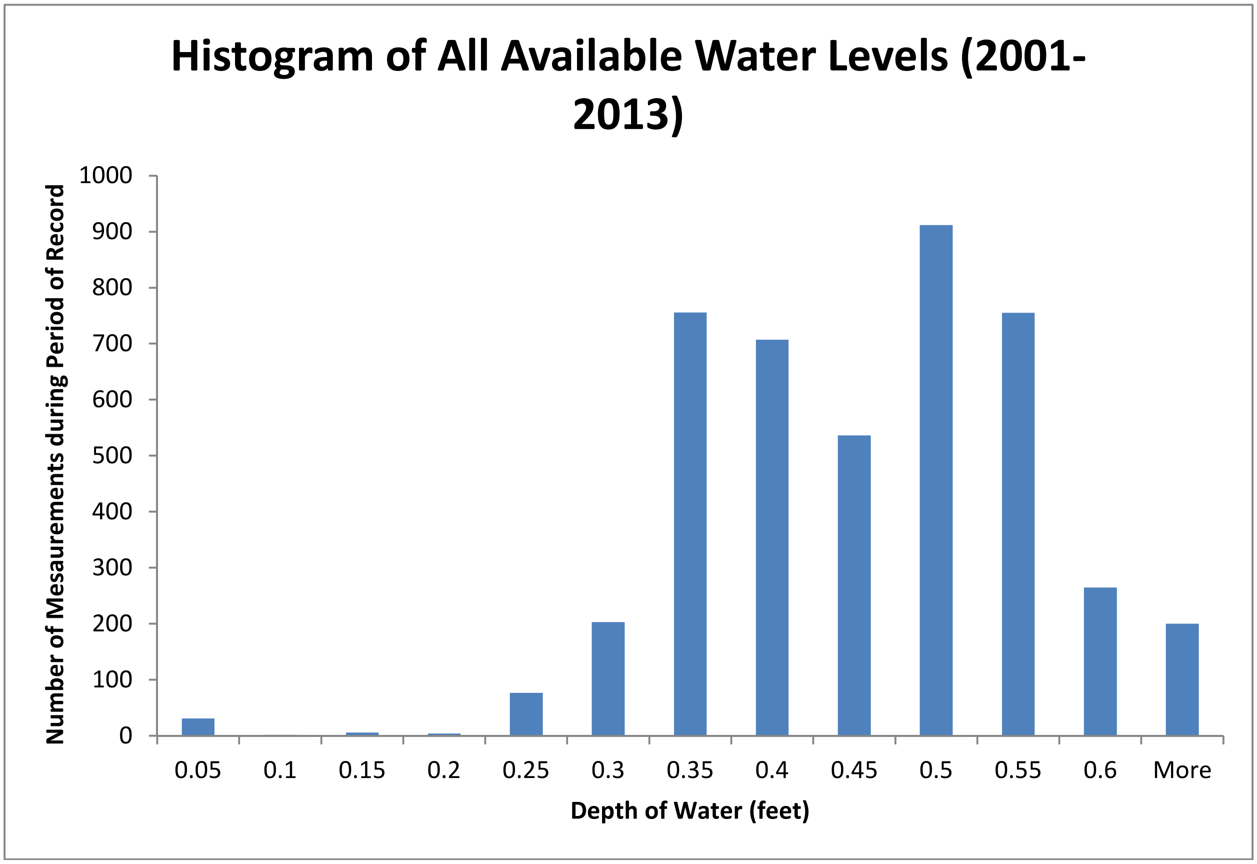

Figure 5. Histogram of all available water levels from Cienega Creek streamgage

The prediction of future impacts takes these existing baseline conditions—i.e., the last 12 years of real water level measurements on Cienega Creek—and superimposes a given modeled drawdown. The probability for Cienega Creek of being dry (and average dry days per year) under these future predicted conditions can then be calculated. In other words, we are predicting what the outcome would be if 1) a similar period of record occurred in the future, and 2) drawdown as modeled occurred in the future.

This is graphically illustrated below (figures 6 and 7), for a modeled drawdown of 0.2 feet.

Cienega Creek running dry is not the only negative outcome that could occur. Other negative outcomes include extremely low depths of water. The probability of extremely low water depths (less than 0.2 feet) has also been calculated for existing baseline conditions and for modeled drawdown superimposed on existing baseline conditions.

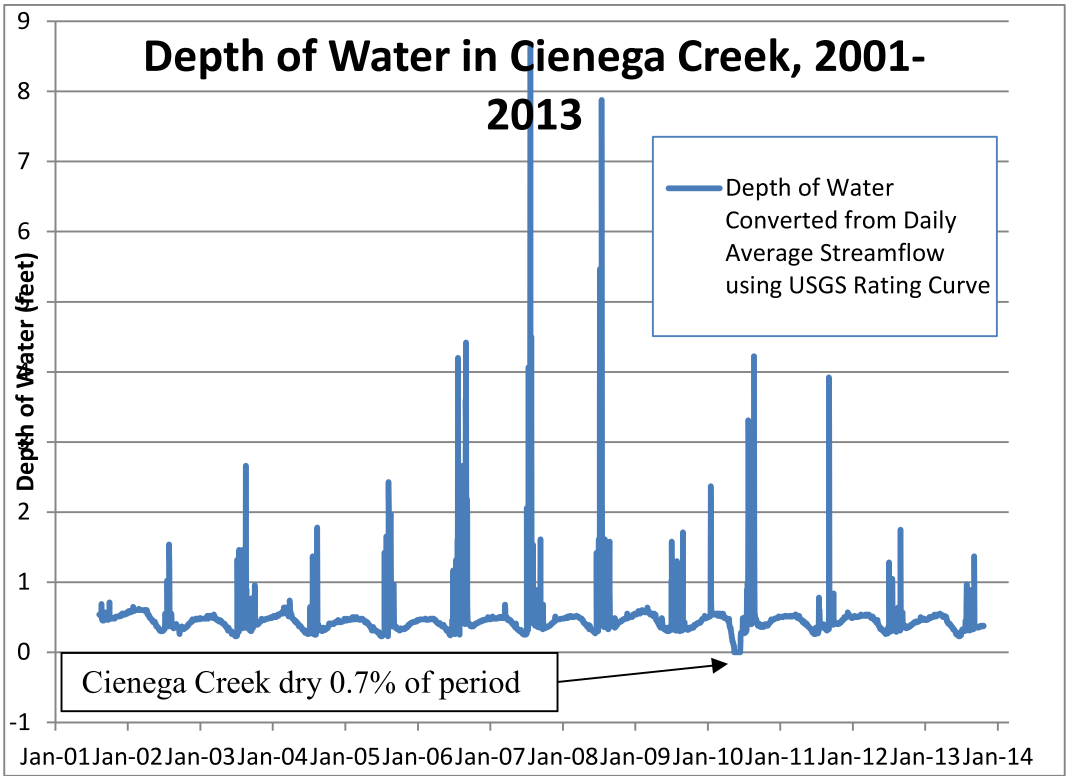

Figure 6. Existing baseline conditions

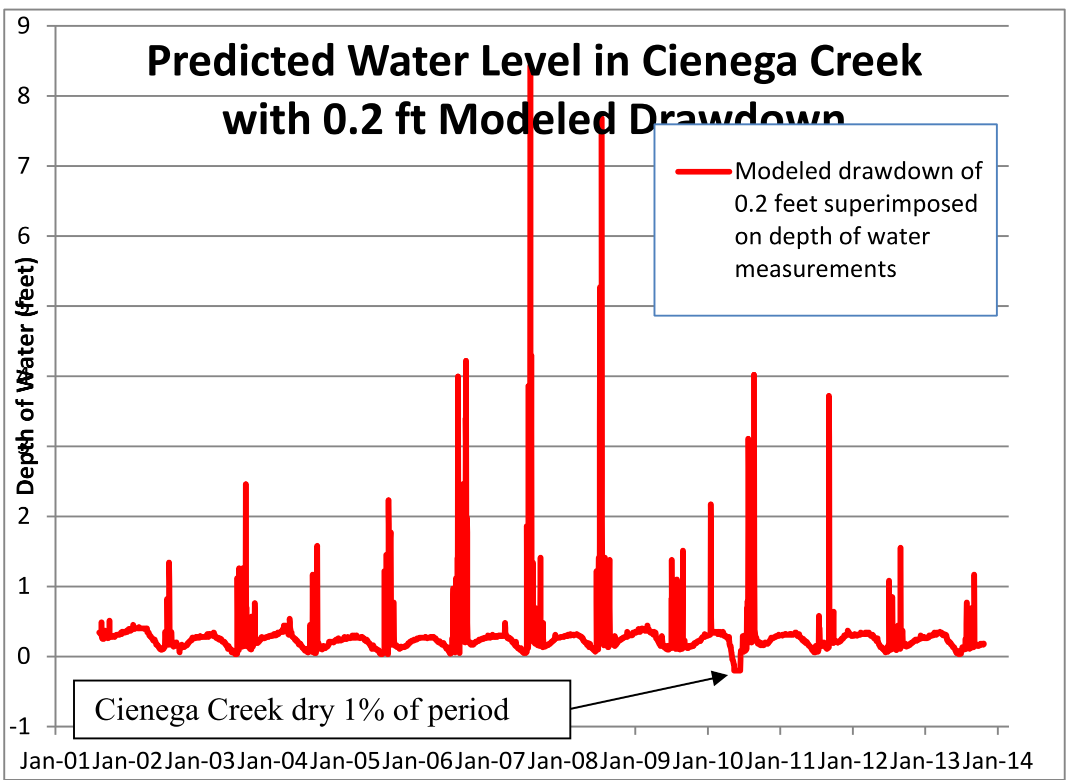

Figure 7. Modeled drawdown superimposed on existing baseline conditions

Precision and Limitation of Modeled Impact

It should also be noted that the precision of the modeled impacts is limited to one tenth of a foot (0.1 feet). While modeled output can be given to any degree of precision needed, the analyses presented in this memo are making use of the entire range of modeling runs including all sensitivity analyses. The results from the sensitivity analyses were provided to the Forest in a format that precluded precision greater than 0.1 feet, and this has necessarily been used as the level of precision for this analysis.

Modeled drawdown less than 0.1 feet has been characterized as "no impact."

Contribution to Cienega Creek from Empire Gulch and Gardner Canyon

In addition to groundwater contribution to baseflow along the main stem of Upper Cienega Creek, Cienega Creek also receives contribution to streamflow from several perennial tributaries, including Empire Gulch, Mattie Canyon, and Gardner Canyon. No streamflow measurements or field observations have been identified that would assist in quantifying the percent contribution of these tributaries to streamflow in Cienega Creek. In lieu of this, the percent contributing watershed area has been used as a surrogate for percent contribution of these perennial tributaries to streamflow in Upper Cienega Creek. The contributing watershed to the USGS streamgage is approximately 127,000 acres. Of this, Empire Gulch represents 14,100 acres (11%) and Gardner Canyon represents 32,500 acres (26%).

It is recognized that any drawdown affecting streamflow in either Empire Gulch or Gardner Canyon would also reduce streamflow in Upper Cienega Creek. The most critical time of year for assessing streamflow is during the low baseflow period of May and June. Median depth of water during this time of year is about 0.3 feet. For the purposes of analysis, a trigger of 0.3 feet was used for elimination of flow from both Empire Gulch and Gardner Canyon. If modeled drawdown equals or exceeds 0.3 feet in these locations, it is assumed that flow from these sources would cease during the critical low flow months, and that no contribution to Cienega Creek would occur from these sources. The analysis assumes that exceeding a modeled drawdown of 0.3 feet in Empire Gulch would result in an 11% loss of flow to Cienega Creek from Empire Gulch, or exceeding a modeled drawdown of 0.3 feet in Gardner Canyon would result in a 26% loss of flow to Cienega Creek from Gardner Canyon. Note that the trigger is the only part of the analysis based on low flow during May/June; the water loss triggered is applied to the entire period of record.

This loss of flow needs to be translated to an additional drawdown that can be superimposed along with the modeled drawdown on the existing baseline conditions. Baseflow depth of water typically ranges from about 0.3 feet (during May/June) to about 0.5 feet (during January). Losses from Empire Gulch and Gardner Canyon are based off of the larger of these two numbers, 0.5 feet. Therefore, this would translate to an additional 0.05 feet of drawdown in Cienega Creek due to the losses from Empire Gulch (11% of 0.5 feet) and an additional 0.13 feet of drawdown in Cienega Creek due to the losses from Gardner Canyon (26% of 0.13 feet).

It is recognized that this is a simplistic approach, and that the relationship between flow and depth is not linear, and that the contribution of Empire Gulch and Gardner Canyon could be diminished even if the trigger is not exceeded. These limitations are acknowledged, and conservative approaches have been selected to offset these limitations.

<u>Calculations of Impact</u>

Detailed calculations for determining the probabilities of Cienega Creek a) going dry, and b) experiencing water levels less than 0.2 feet, are included as Attachment 1. The following tables are included:

A. Predicted modeled drawdown at 50 years (near-term), 150 years (long-term), and 1,000 years (long-term). These values are presented in the Groundwater Quantity section of Chapter 3 of the FEIS. Each time period shown in the table includes:
    a. The smallest drawdown from any of the modeling runs
    b. The largest drawdown from any of the modeling runs
    c. The drawdown from each of the best-fit modeling runs from each of the three models.
B. The probability of the stream going dry under existing baseline conditions. "Existing baseline conditions" means the 12-year monitoring period between 2001 and 2013 shown in Figure 6. The probability is also presented as the average number of days per year these conditions occurred. This calculation was done using the table included as Attachment 2. Attachment 2 contains all 4,554 daily depth of water measurements for the Cienega Creek streamgage during the period of record, ranked from highest to lowest. The probability that a water level will be exceeded, the probability that it will not be exceeded, and the average number of days annually this occurs (probability times 365) are shown.
C. The probability of the stream experiencing extremely low water levels (less than 0.2 feet) under existing baseline conditions shown in Figure 6. The probability is

also presented as the average number of days per year these conditions occurred.

D. Based on the predicted model drawdown (item "A" above), whether the trigger for extermination of flow from Empire Gulch or Gardner Canyon is exceeded, and what additional drawdown needs to be superimposed on the modeled drawdown.
E. Combined drawdown from predicted model drawdown (item "A" above) and flow reduction from Empire Gulch/Gardner Canyon (item "D" above).
F. The probability of the stream going dry, if the revised modeled drawdowns (item "E" above) were superimposed on the existing baseline conditions (Figure 6). This is calculated using the table in Attachment 2. For water levels that do not perfectly match an entry in Attachment 2, the next highest water level was used.
G. The average number of days per year the stream would go dry, if the revised modeled drawdowns (item "E" above) were superimposed on the existing baseline conditions (Figure 6).
H. The probability of extremely low flow conditions occurring, if the revised modeled drawdowns (item "E" above) were superimposed on the existing baseline conditions (Figure 6).
I. The average number of days of extremely low flow conditions occurring, if the revised modeled drawdowns (item "E" above) were superimposed on the existing baseline conditions (Figure 6).

Responsiveness of Approach to Cooperating Agency Concerns

This approach is responsive to the concerns previously presented.

- The approach is quantitative, not qualitative.
- The approach makes no use of medians or averages, but rather takes into account all water levels experienced on Cienega Creek, including seasonal variations and extremely low flow periods. This period also represents a period of significant drought, and therefore would not be overly optimistic of future conditions.
- The assessment of impacts is not arbitrary. There are no subjective measures used in the superimposition analysis. There are two selected values that could be perceived as subjective, but have logical underpinnings:
    - The use of 0.1 feet as the limit of precision for assigning impacts (discussed below). This is not arbitrary or subjective, but is driven by the

precision of the underlying modeling data (i.e., the modeling sensitivity analysis results).

- The use of 0.2 feet to designate "extremely low water depths". As noted previously, water levels typically get down to 0.3 feet during summer months. A water level of 0.2 feet or lower therefore represents conditions that are not normally experienced on the stream

Cooperating agencies have also raised concerns that significant climatic trends—drought and climate change—as well as increasing water demands in the basin could result in much worse impacts than predicted. This is recognized and discussed in the FEIS. <u>However, these exacerbating trends or conditions do not preclude the need to actually analyze the impacts that would occur from the mine</u>. Whether these exacerbating conditions would make impacts worse or not, superimposing the predicted drawdown on the existing baseline conditions informs the decision of the Forest Supervisor by analyzing the increased risk that would occur solely because of the decision.

REFERENCES

Bodner, G. and Simms, K. 2008. State of the Las Cienegas National Conservation Area. Part 3. Condition and Trend of Riparian Target Species, Vegetation and Channel Geomorphology. January.

ATTACHMENT 1

DETAILED CALCULATION TABLES

ATTACHMENT 2

RANKING OF ALL DEPTH OF WATER MEASUREMENTS

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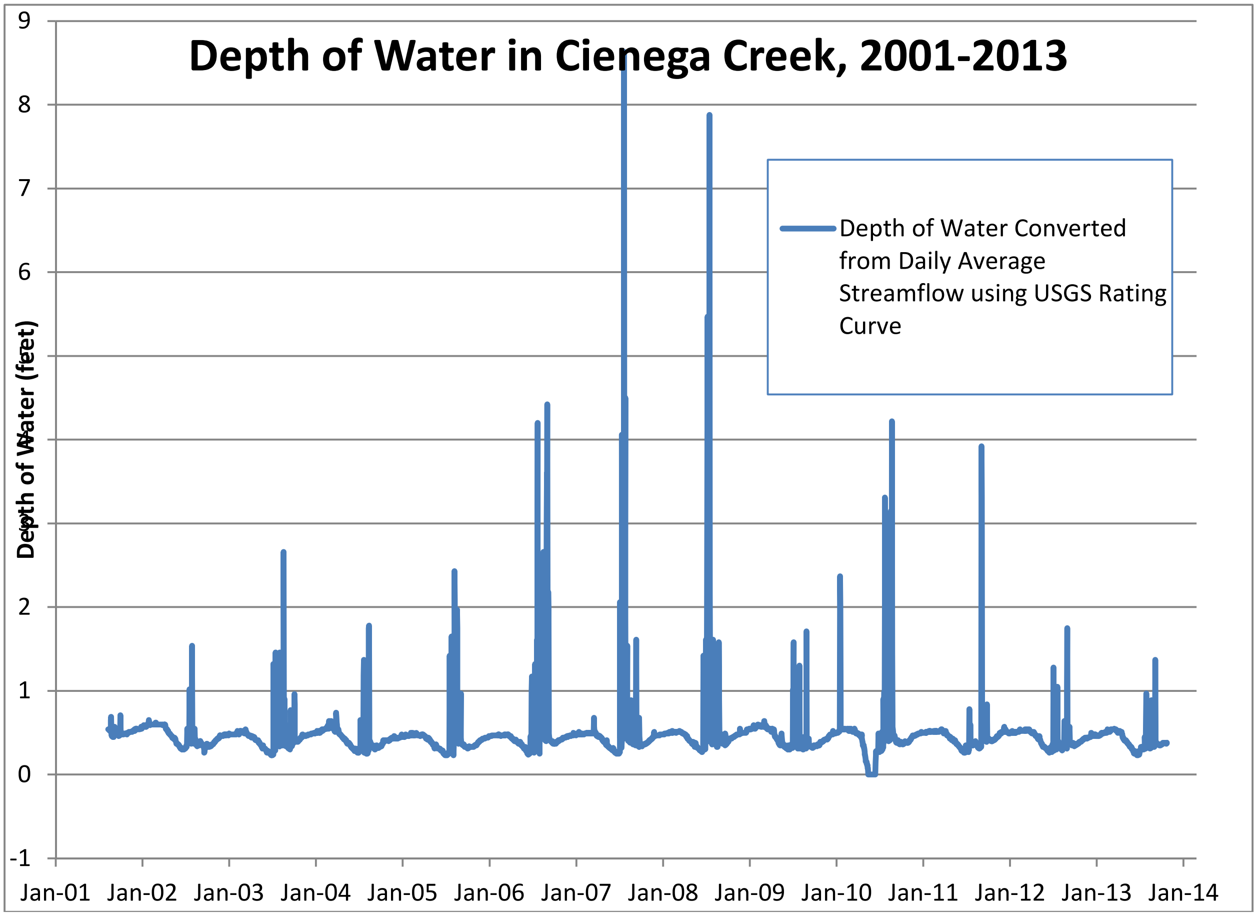

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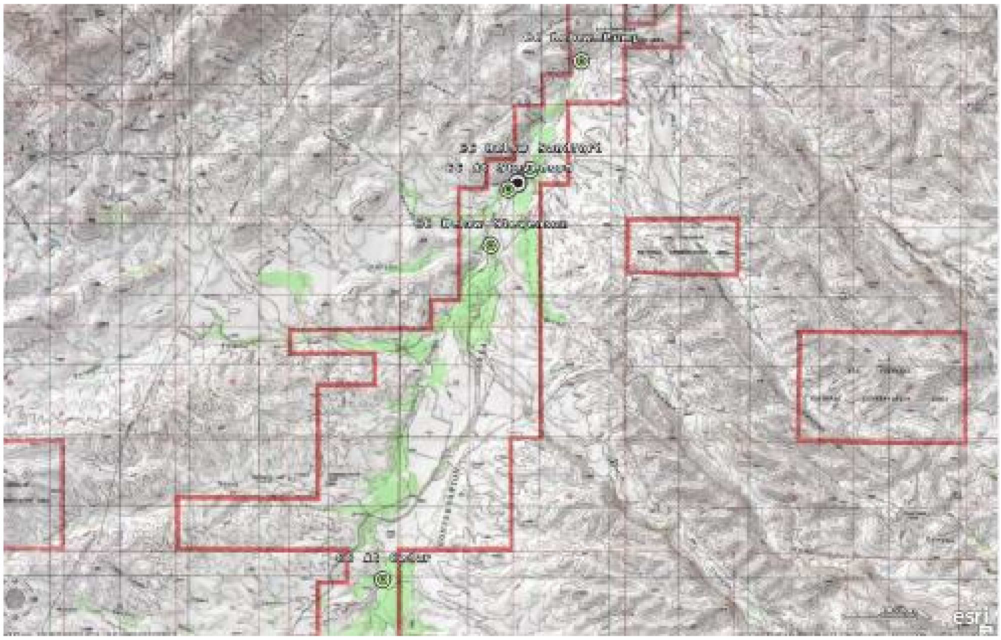

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Applicability of Streamgage as a Surrogate to Upper Cienega Creek

Water levels clearly vary widely in Cienega Creek. This is not unexpected, as channel geometry and flow characteristics are highly variable, even within short distances. The streamgage depth of water values fall more-or-less in the middle of the observed data: 12 observed depth measurements are higher than the streamgage, 15 observed depth measurements are lower than the streamgage (figure 4). The comparison of specific dates is more biased: 3 observed depth measurements are higher than the streamgage, 7 observed depth measurements are lower than the streamgage.

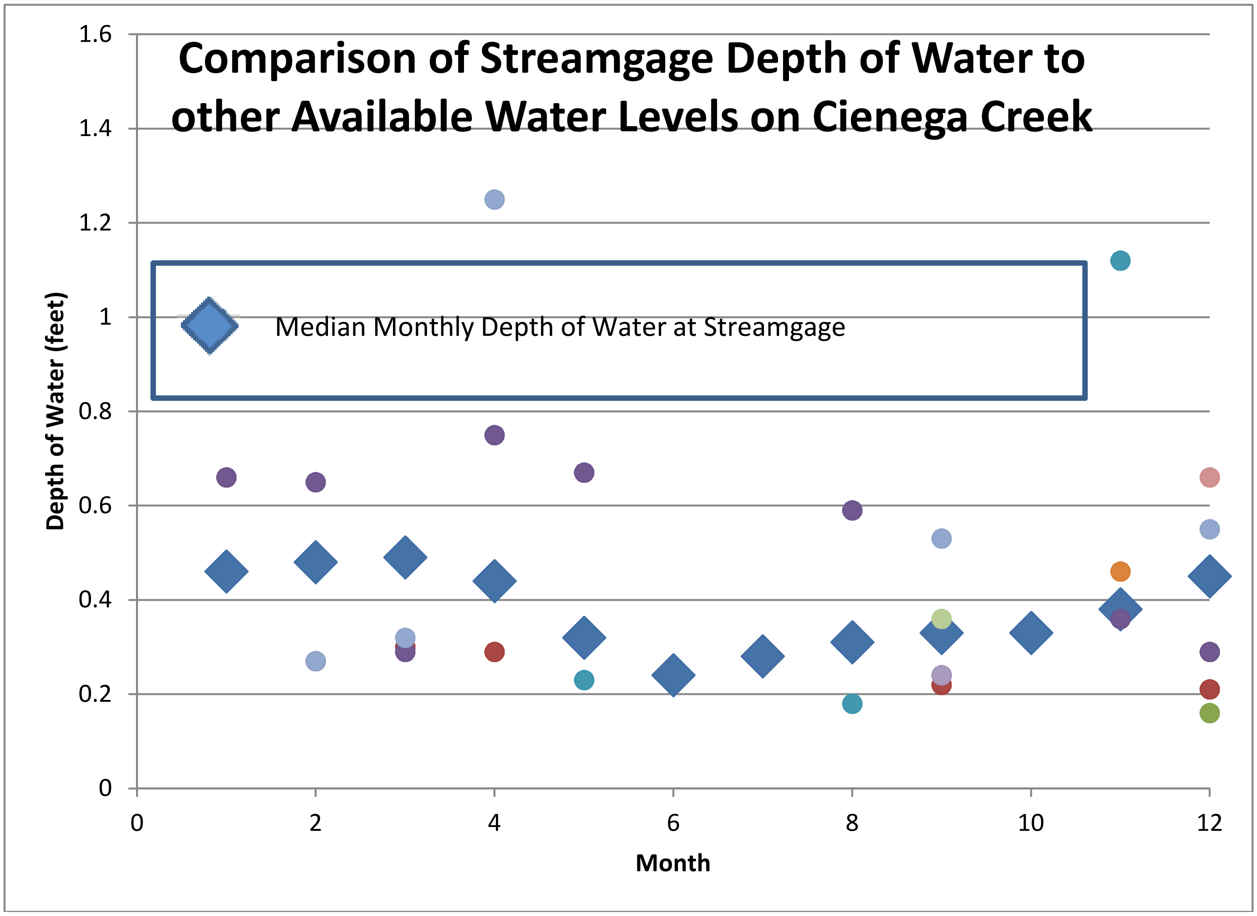

Figure 4. Comparison of streamgage median water levels to other water level measurements on Cienega Creek

The use of the streamgage as a surrogate for all of Upper Cienega Creek seems reasonable as an approximation of typical conditions along Upper Cienega Creek, given the limitations of the analysis. Actual impacts to streamflow at any given location along Upper Cienega Creek would depend on the specific channel geometry, hydraulic connection with the regional aquifer, and riparian vegetation characteristics at a specific location. This is evident from the high longitudinal variability exhibited during annual stream presence/absence monitoring conducted downstream within the Pima County Cienega Creek Natural Preserve, in which some sections of the creek are entirely dry while other areas of the creek remain wet. In addition, at any given location the channel geometry is constantly shifting over time in response to sediment loads and changes in flow unless there is good channel control, such as at the USGS streamgage. It is impossible to predict exactly how any given cross-section would change over the extremely long periods of time used in the analysis.

The analysis is not intended to capture these nuances. The purpose of the analysis is to generalize the potential impacts that would occur along a long stretch of channel, recognizing that localized impacts can be greater or less, just as impacts during drought cycles can be greater and impacts during wet climatic cycles can be less. The streamgage data appear to be reasonable for this type of generalized analysis, to use as a surrogate for likely impacts along all of Upper Cienega Creek.

Applicability of Streamgage as a Surrogate to Empire Gulch and Gardner Canyon

The applicability of the Cienega Creek streamgage as a surrogate for flow impacts along Empire Gulch is not as well justified, given the paucity of measured water depths in Empire Gulch. The Cienega Creek streamgage falls within the range observed in Empire Gulch, but the entire set of data points numbers only two.

The prediction of impacts looks at several points in time: near-term (up to 50 years after closure), and long-term (up to 1,000-years after closure). At 1,000 years in the future, the relevance of the Cienega Creek gage to Empire Gulch is a moot point, as the drawdowns predicted by the models are great enough to predict significant drying under almost any analysis technique.

In the near-term, based on anecdotal descriptions of Empire Gulch, the Cienega Creek streamgage is probably a reasonable surrogate for lower Empire Gulch near the confluence, but may substantially overestimate water depth farther upstream.

Lacking better water depth information for Empire Gulch, the Cienega Creek streamgage has been used as a surrogate, but the likelihood of flows being shallower farther upstream is explicitly acknowledged in the analysis.

No depth of water or streamflow information has been uncovered for Gardner Canyon. The Cienega Creek streamgage has been used as a surrogate for Gardner Canyon as well, but again the likelihood of flows being shallower is explicitly acknowledged in the analysis.

Prediction of Impacts

During the various rounds of review, the following general concerns were raised:

- The approach was too qualitative.
- The approach was not conservative enough. Critical periods should be given more focus, not just medians or averages.

- The approach used assumptions that were arbitrary and not supported. While recognizing that these assumptions may necessarily be based on professional judgment, they were felt to be too subjective to adequately reflect the potential impacts.
- The approach should rely on a range of impacts, or a risk assessment approach, rather than selecting a single outcome.

The following approach was developed to respond to these concerns. It builds off the strength of having a period of record of detailed water levels along Cienega Creek (2001-present). This period of record is pertinent for several reasons. First, this represents a period of significant drought, and therefore ought to be relatively conservative. Second, this period of record incorporates all of the normal seasonal highs and lows, including the most critically low-flow periods (May/June). Third, this period of record includes periods when Cienega Creek actually dried. This allows us to estimate the probability under existing baseline conditions for Cienega Creek to dry, and estimate the average days per year that dry conditions occur. The probabilities under existing baseline conditions are summarized in table 2. A histogram of existing baseline water levels is shown in figure 5.

Table 2. Percent of time water levels are exceeded during period of record

Depth of Water (feet)	Percent of Time Exceeded
0.6	4.5%
0.55	8.8%
0.5	22.5%
0.45	45.7%
0.4	59.9%
0.35	75.8%
0.3	91.2%
0.25	97.3%
0.2	99.0%
0.15	99.1%
0.1	99.2%
DRY	99.3% (i.e., dry 0.7% of time)

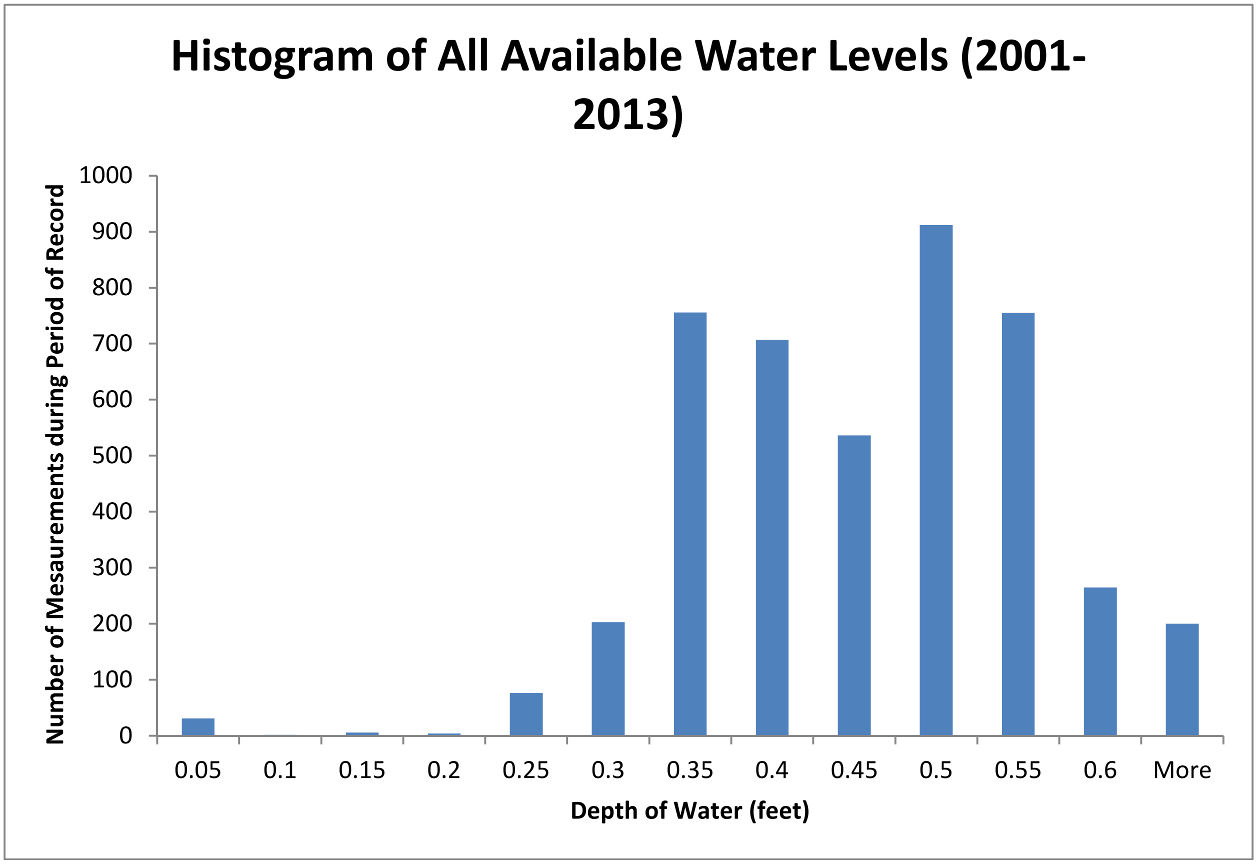

Figure 5. Histogram of all available water levels from Cienega Creek streamgage

The prediction of future impacts takes these existing baseline conditions—i.e., the last 12 years of real water level measurements on Cienega Creek—and superimposes a given modeled drawdown. The probability for Cienega Creek of being dry (and average dry days per year) under these future predicted conditions can then be calculated. In other words, we are predicting what the outcome would be if 1) a similar period of record occurred in the future, and 2) drawdown as modeled occurred in the future.

This is graphically illustrated below (figures 6 and 7), for a modeled drawdown of 0.2 feet.

Cienega Creek running dry is not the only negative outcome that could occur. Other negative outcomes include extremely low depths of water. The probability of extremely low water depths (less than 0.2 feet) has also been calculated for existing baseline conditions and for modeled drawdown superimposed on existing baseline conditions.

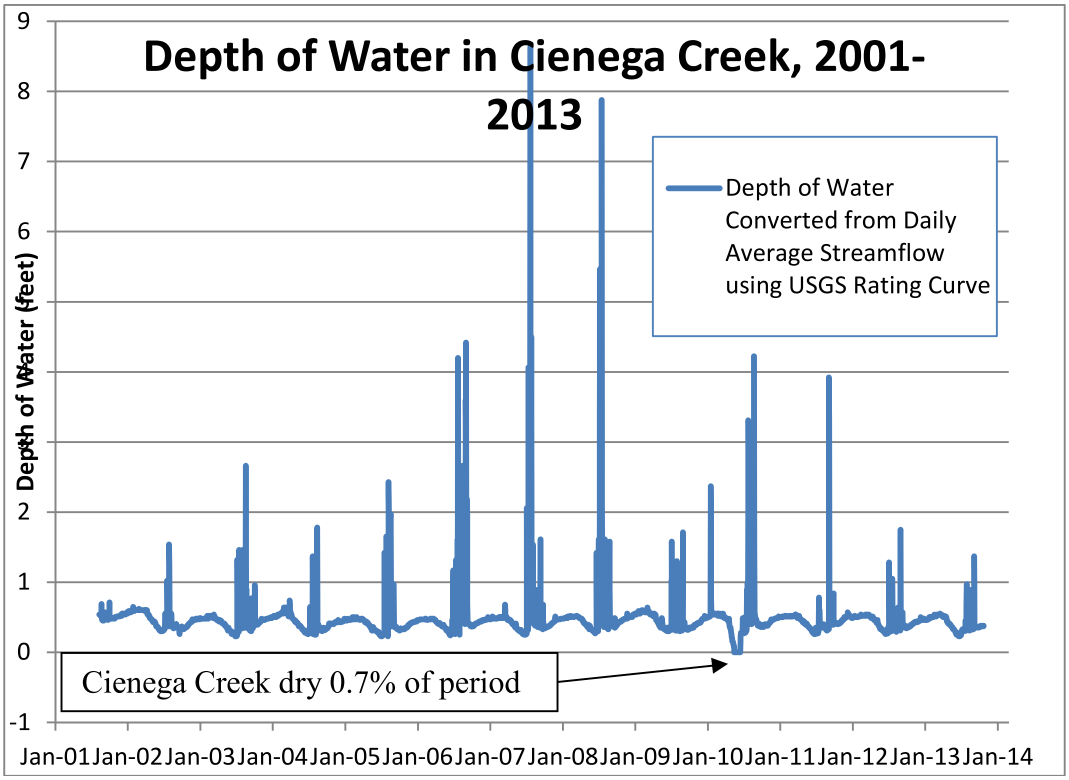

Figure 6. Existing baseline conditions

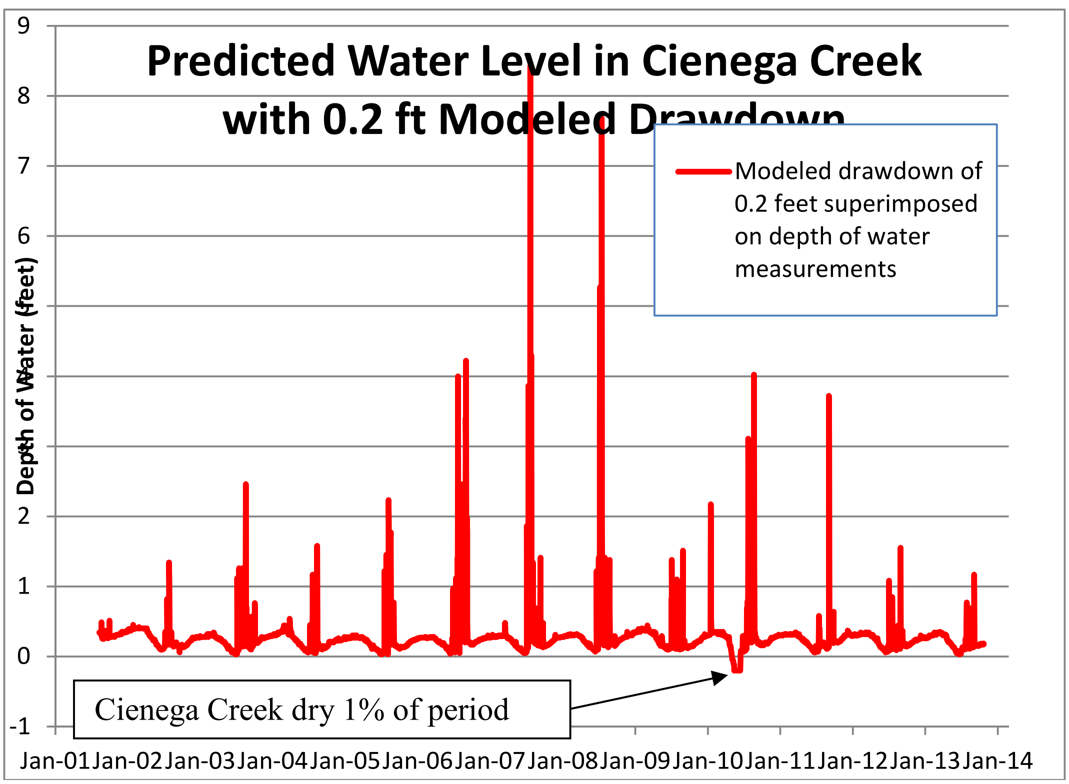

Figure 7. Modeled drawdown superimposed on existing baseline conditions

Precision and Limitation of Modeled Impact

It should also be noted that the precision of the modeled impacts is limited to one tenth of a foot (0.1 feet). While modeled output can be given to any degree of precision needed, the analyses presented in this memo are making use of the entire range of modeling runs including all sensitivity analyses. The results from the sensitivity analyses were provided to the Forest in a format that precluded precision greater than 0.1 feet, and this has necessarily been used as the level of precision for this analysis.

Modeled drawdown less than 0.1 feet has been characterized as "no impact."

Contribution to Cienega Creek from Empire Gulch and Gardner Canyon

In addition to groundwater contribution to baseflow along the main stem of Upper Cienega Creek, Cienega Creek also receives contribution to streamflow from several perennial tributaries, including Empire Gulch, Mattie Canyon, and Gardner Canyon. No streamflow measurements or field observations have been identified that would assist in quantifying the percent contribution of these tributaries to streamflow in Cienega Creek. In lieu of this, the percent contributing watershed area has been used as a surrogate for percent contribution of these perennial tributaries to streamflow in Upper Cienega Creek. The contributing watershed to the USGS streamgage is approximately 127,000 acres. Of this, Empire Gulch represents 14,100 acres (11%) and Gardner Canyon represents 32,500 acres (26%).

It is recognized that any drawdown affecting streamflow in either Empire Gulch or Gardner Canyon would also reduce streamflow in Upper Cienega Creek. The most critical time of year for assessing streamflow is during the low baseflow period of May and June. Median depth of water during this time of year is about 0.3 feet. For the purposes of analysis, a trigger of 0.3 feet was used for elimination of flow from both Empire Gulch and Gardner Canyon. If modeled drawdown equals or exceeds 0.3 feet in these locations, it is assumed that flow from these sources would cease during the critical low flow months, and that no contribution to Cienega Creek would occur from these sources. The analysis assumes that exceeding a modeled drawdown of 0.3 feet in Empire Gulch would result in an 11% loss of flow to Cienega Creek from Empire Gulch, or exceeding a modeled drawdown of 0.3 feet in Gardner Canyon would result in a 26% loss of flow to Cienega Creek from Gardner Canyon. Note that the trigger is the only part of the analysis based on low flow during May/June; the water loss triggered is applied to the entire period of record.

This loss of flow needs to be translated to an additional drawdown that can be superimposed along with the modeled drawdown on the existing baseline conditions. Baseflow depth of water typically ranges from about 0.3 feet (during May/June) to about 0.5 feet (during January). Losses from Empire Gulch and Gardner Canyon are based off of the larger of these two numbers, 0.5 feet. Therefore, this would translate to an additional 0.05 feet of drawdown in Cienega Creek due to the losses from Empire Gulch (11% of 0.5 feet) and an additional 0.13 feet of drawdown in Cienega Creek due to the losses from Gardner Canyon (26% of 0.13 feet).

It is recognized that this is a simplistic approach, and that the relationship between flow and depth is not linear, and that the contribution of Empire Gulch and Gardner Canyon could be diminished even if the trigger is not exceeded. These limitations are acknowledged, and conservative approaches have been selected to offset these limitations.

Calculations of Impact

Detailed calculations for determining the probabilities of Cienega Creek a) going dry, and b) experiencing water levels less than 0.2 feet, are included as Attachment 1. The following tables are included:

A. Predicted modeled drawdown at 50 years (near-term), 150 years (long-term), and 1,000 years (long-term). These values are presented in the Groundwater Quantity section of Chapter 3 of the FEIS. Each time period shown in the table includes:
    a. The smallest drawdown from any of the modeling runs
    b. The largest drawdown from any of the modeling runs
    c. The drawdown from each of the best-fit modeling runs from each of the three models.
B. The probability of the stream going dry under existing baseline conditions. "Existing baseline conditions" means the 12-year monitoring period between 2001 and 2013 shown in Figure 6. The probability is also presented as the average number of days per year these conditions occurred. This calculation was done using the table included as Attachment 2. Attachment 2 contains all 4,554 daily depth of water measurements for the Cienega Creek streamgage during the period of record, ranked from highest to lowest. The probability that a water level will be exceeded, the probability that it will not be exceeded, and the average number of days annually this occurs (probability times 365) are shown.
C. The probability of the stream experiencing extremely low water levels (less than 0.2 feet) under existing baseline conditions shown in Figure 6. The probability is

also presented as the average number of days per year these conditions occurred.

D. Based on the predicted model drawdown (item “A” above), whether the trigger for extermination of flow from Empire Gulch or Gardner Canyon is exceeded, and what additional drawdown needs to be superimposed on the modeled drawdown.
E. Combined drawdown from predicted model drawdown (item “A” above) and flow reduction from Empire Gulch/Gardner Canyon (item “D” above).
F. The probability of the stream going dry, if the revised modeled drawdowns (item “E” above) were superimposed on the existing baseline conditions (Figure 6). This is calculated using the table in Attachment 2. For water levels that do not perfectly match an entry in Attachment 2, the next highest water level was used.
G. The average number of days per year the stream would go dry, if the revised modeled drawdowns (item “E” above) were superimposed on the existing baseline conditions (Figure 6).
H. The probability of extremely low flow conditions occurring, if the revised modeled drawdowns (item “E” above) were superimposed on the existing baseline conditions (Figure 6).
I. The average number of days of extremely low flow conditions occurring, if the revised modeled drawdowns (item “E” above) were superimposed on the existing baseline conditions (Figure 6).

Responsiveness of Approach to Cooperating Agency Concerns

This approach is responsive to the concerns previously presented.

- The approach is quantitative, not qualitative.
- The approach makes no use of medians or averages, but rather takes into account all water levels experienced on Cienega Creek, including seasonal variations and extremely low flow periods. This period also represents a period of significant drought, and therefore would not be overly optimistic of future conditions.
- The assessment of impacts is not arbitrary. There are no subjective measures used in the superimposition analysis. There are two selected values that could be perceived as subjective, but have logical underpinnings:
  - The use of 0.1 feet as the limit of precision for assigning impacts (discussed below). This is not arbitrary or subjective, but is driven by the

precision of the underlying modeling data (i.e., the modeling sensitivity analysis results).

- The use of 0.2 feet to designate "extremely low water depths". As noted previously, water levels typically get down to 0.3 feet during summer months. A water level of 0.2 feet or lower therefore represents conditions that are not normally experienced on the stream

Cooperating agencies have also raised concerns that significant climatic trends—drought and climate change—as well as increasing water demands in the basin could result in much worse impacts than predicted. This is recognized and discussed in the FEIS. <u>However, these exacerbating trends or conditions do not preclude the need to actually analyze the impacts that would occur from the mine</u>. Whether these exacerbating conditions would make impacts worse or not, superimposing the predicted drawdown on the existing baseline conditions informs the decision of the Forest Supervisor by analyzing the increased risk that would occur solely because of the decision.

REFERENCES

Bodner, G. and Simms, K. 2008. State of the Las Cienegas National Conservation Area. Part 3. Condition and Trend of Riparian Target Species, Vegetation and Channel Geomorphology. January.

ATTACHMENT 1

DETAILED CALCULATION TABLES

ATTACHMENT 2

RANKING OF ALL DEPTH OF WATER MEASUREMENTS